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Developing a Universal Data Access Layer leveraging ADO.NET, C# and Factory Design Pattern

by Naveed Zaheer

CATEGORIES: Site Design, Data Access/ADO.NET
ARTICLE TYPE: Tutorial

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ABSTRACT

In this article Naveed Zaheer shows us how to build a thin universal data access layer at the top of ADO.NET using Design Patterns and .NET Framework. This component layer, which will be based on ADO.NET, will provide access to OLE DB Managed Providers as well as SQL Server Managed Providers through a single interface. It will be extensible so that in the future we can add access to other Managed providers when they become available.

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ARTICLE

Editor's Note: This article's code has been updated to work with the final release of the .Net framework.

Ideally, every software application will access the data from all possible data sources in the same manner. Every application will be able to manipulate data in every possible way. But we do not live in a perfect world. There are limitations on how we can or cannot access certain types of data. In the past few years Microsoft's ActiveX Data Object (ADO) has revolutionized data access mechanism. With the arrival of .NET, comes ADO.NET, which truly is the next generation of the ADO data species. In this article, readers will learn how to build a thin universal data access layer at the top of ADO.NET using Design Patterns and .NET Framework. This component layer, which will be based on ADO.NET, will provide access to OLE DB Managed Providers as well as SQL Server Managed Providers through a single interface. It will be extensible so that in the future we can add access to other Managed providers when they become available.

This article does not require a prior knowledge of Design Patterns. However, familiarity with Object Oriented Design and Analysis techniques is recommended. A brief overview of Design Patterns is covered later in the article. The discussion on n-tier (Presentation Tier, Business Tier, Data Tier) design and architecture is beyond the scope of this article. It assumes that readers have some familiarity with n-tier design.

An Overview of Data Access Strategies

Before we dive into ADO.NET, let's go through a brief overview of history of data access on Microsoft platforms including Windows and DOS. It all started with the arrival of ODBC (Open Database Connectivity). ODBC provided a single API-style interface to access heterogeneous data sources. Components called ODBC drivers provided the abstraction layer between databases and ODBC interface. Theoretically an application could switch to any database without modifying a single line of data access code for which an ODBC driver was available. Because of the API-style interface the use of ODBC was much more rampant in C/C++ applications than in Visual Basic applications. Then came a slew of data access frameworks such as DAO (Data Access Objects) and RDO (Remote Data Objects). DAO basically came with Visual Basic to supply developers with a data access class library for Microsoft's own desktop database named "Access". On the other hand RDO just provided an object-wrapper for ODBC. Although each of these solutions was effective for accessing certain types of data source, none provided a

comprehensive solution. The arrival of ADO (Active Data Objects) a few years ago provided a far from elegant, but better solution to common data access problems. ADO is a user-friendly object wrapper around Microsoft's data access technology OLE DB. This object model provides uniform access relational as well as non-relational data. With the many great features it provides, the best one is a single interface to access all type of data sources. Just like ODBC drivers for ODBC, you have to develop OLE DB providers as an abstraction layer between database and OLE DB. From ODBC to ADO one theme was consistent i.e. a single interface to access different types of data sources. Although it was useful to switch between data sources without making many changes to the data access layer, in many cases it took away a chunk from performance. The availability of OLE DB provider for SQL Server alleviated the problem a little bit, but still performance was the issue. Because now it was possible to access SQL Server data by using this native OLE DB provider instead of OLE Db Provider for ODBC.

Next Generation of Data Access - ADO.NET

With the arrival of .NET came ADO.NET. ADO.NET is not here to replace classic ADO, but to offer a different approach to data access. Classic ADO offered disconnected recordsets but still most of the data access was in connected mode. What ADO.NET offers is a disconnected approach. Also, to boost performance it offers a separate, Managed Provider for different types of data sources. The idea is to take advantage of native database capabilities, instead of building a single interface across all backends based upon least common denominator. At the time of writing only three managed providers i.e. MS SQL Server, OLE DB and ODBC are available. Manager Provider for SQL Server goes directly through TDS (Tabular Data Stream), which is SQL Server's native data interface. It is only supported for SQL Server 7.0 or above. This way if you are accessing data from MS SQL Server, you get a big performance boost compared to OLE DB provider. Now we have separate classes to deal with when accessing data for OLE DB and MS SQL Server data sources. Suppose that you are using OLE DB data provider to access data from an Oracle database for your .NET application. In the meantime, an ADO.NET Managed Provider for Oracle native data interface becomes available from Microsoft or a 3rd party. Now to use the new Manager Provider, you may have to alter all your data access code.

Many businesses are running a mixture of different databases. Imagine a company's e-Commerce site for example. It may have a variety of databases that it uses for different purposes. For example, DB2 database, where its entire inventory has stored; Oracle database, where it's entire customer data is stored; and MS SQL Server database where it is planning to migrate in the future. What if we can have a single interface to access all these Managed Providers without sacrificing performance? This interface should be neither too general nor too specific. Whenever possible, this interface should try to expose the native Provider functionality instead of providing a wrapper for it. It should cover the entire common functionality supported by all the Manager Providers. The abstraction layer it provides should not be so thick that it degrades performance.

There are different ways to solve this problem. One way is to have a single class where each method has a switch-case statement to handle different data providers. Sample code for this solution is shown below:

```
public override void Execute(ProviderType ctProviderType,CommandType ctStatement, string
{
switch(ctProviderType)
{
       case ProviderType.MSSqlClient:
       .
//Do Stuff Here for SqlClient
       .
objSqlCommand.ExecuteNonQuery()
       break;

       case ProviderType.MSOleDb:
       .
//Do Stuff Here for OleDb
       .
objOleDbCommand.ExecuteNonQuery()
       break;

       default:
       //Do Nothing
       break;
       }

}
```

However, this is not an elegant solution, because it will make code unnecessarily complex. Each time a new Managed Provider becomes available you will have to modify that class. After you make a change for one Managed Provider, you will have to regression test the component against all Managed Providers just to make sure you did not break anything.

Overview of Design Patterns

Let's see how Design Patterns can help us solving this problem. However, before we do that let's get a brief look at what `Design Patterns` are. `Design Patterns` are the robust solutions of frequently occurring problems, which evolve, because of object-oriented development, over a period of decades. These are not new techniques, which were never used before. You may have been using Design Patterns before without any knowledge of doing so. For example if you have programmed with Visual C++ MFC you must have used Document/View Architecture, which itself is based on a Design Pattern. If you have programmed with ATL (Active Template Library) or STL (Standard Template Library) then you must have used templates. A template is a type of Behavioral Design Pattern. In COM, design of interface `IClassFactory` is based on Factory Design Pattern. Singleton is a common Design Patten, which is used very often. For a detailed discussion about Design Patterns, please refer to the book mentioned in the Helpful Links section later in this article. Design Patterns are divided into three categories:

- 1) Creational: Design Patterns in this category deal with object instantiation. Factory and Singleton belong to this category.
- 2) Structural: Design Patterns in this category deal with object and class composition. Adapter and Facade belong to this category.
- 3) Behavioral: Design Patterns in this category deal with algorithms and assigning object responsibilities. Mediator and Command belong to this category.

Factory Design Pattern

Sometimes an application or a framework does not know at runtime what kind of objects it has to create at runtime. It may only know about the abstract class for those objects. However, these abstract classes or interfaces cannot be instantiated. In other words, application only knows when to create the object but it does not know the type of the object to create. Factory Design Pattern does solve this problem. **Factory Design Pattern** Method is a Creational Design Pattern. The purpose of Factory method is to create objects. It helps us design an interface that creates objects of appropriate subclasses at runtime. It provides loose coupling eliminating the need to tie application specific classes together.

Factory Design Pattern is defined as "Define an interface for creating an object, but let the subclasses decide which class to instantiate." The Factory method lets a class defer instantiation to subclasses. The Factory Method lets a class defer instantiation to subclasses in the book Design Patterns.

In simple words, Factory Method lets you decide at runtime which subclasses of an abstract base class will be instantiated.

There are different implementations of Factory Method. One particular implementation that we are interested in is "Parameterized Factory method". In this implementation Factory Method is used to create multiple kinds of objects. It accepts a parameter that identifies which type of object to create. All the objects created implement the same interface or subclasses from the same abstract base class. Consider the following example:

```
public class Creator
{
	public static int gintComicBook = 0;
	public static int gintProgrammingBook = 1;
	public static int gintFictionBook = 2;
	public Creator()
	{
	}
	public Book CreateBook(int iBookType)
	{
		switch(iBookType)
		{
			case gintComicBook:
				return new ComicBook();

			case gintProgrammingBook:
				return new ProgrammingBook();

			case gintFictionBook:
				return new FictionBook();

		};
	}
}
```

In the code above function, `CreateBook` of class `Creator` takes an integer as a parameter. Based on that parameter it decides what type of object it is going to create. All the three classes i.e. `ComicBook`, `ProgrammingBook`, `FictionBook`, derive from the same base class Book.

Data Access Layer Implementation

Let's see that how we can use the Parameterized Factory Method implementation to create a single interface for all of the Managed Providers using Factory Method. First, we will have to have a Creator class with a function like `CreateBook`. This function will take a parameter identifying what type of Managed Provider object it has to create. For our implementation, class DataManager is our Creator class. Its function `GetDBAccess`, which has two overloads, behaves the same way as `CreateBook` behaves in the above example. Following is the partial code for DataManager class:

```
public static DBAccess GetDBAccessor(ProviderType ctProviderType,string strConnectionInf
{
	DBAccess objDBAccess;
	switch(ctProviderType)
	{
		case ProviderType.MSSqlClient:
		objDBAccess = new DBAccessSQL(strConnectionInfo);
		break;

		case ProviderType.MSOleDb:
		objDBAccess = new DBAccessOleDb(strConnectionInfo);
		break;

		default:
		objDBAccess = null;
		break;
	}
	return objDBAccess;
}
public static DBAccess GetDBAccessor(ProviderType ctProviderType)
{
	return GetDBAccessor(ctProviderType,"");
}
```

As you can see from the code shown above, both overloads of function `GetDBAccess` take a parameter of type enumeration `ProviderType`. Based on the value of that parameter, it is decided from that object which class will be instantiated. Both classes i.e. `DBAccessOleDb`, `DBAccessSQL`, derive from the same base class `DBAccess`. `DBAccess` is the abstract base class that defines an interface common to all Managed Providers. Following is the partial code shown for the base class `DBAccess`:

```
public abstract class DBAccess : IDisposable
{
	protected string mstrConnectionInfo;
	//public properties
	public abstract string ConnectionInfo
	{
		set;
		get;
	}
	public abstract bool InTransaction
	{
		get;
	}
		//public functions
	public abstract void BeginTransaction();
	public abstract void CommitTransaction();
	public abstract void AbortTransaction();
	public abstract void Execute(CommandType ctStatement,string strSQL);
	public abstract void Execute(CommandType ctStatement,string
	     strSQL,string strTable,out DataSet objDataSet);
	  public abstract void Execute(CommandType ctStatement,string
	            strSQL,out IDataReader objDataReader);
	public abstract void SetParameter(string strName, ParameterDirection
	     pdDirection, ParameterType ptType, int intSize, object objValue);
	public abstract void SetParameter(string strName, ParameterDirection
	     pdDirection, ParameterType ptType, int intSize);
	public abstract void SetParameter(string strName, ParameterDirection
	     pdDirection, ParameterType ptType);
	public abstract void ClearParameters();
	public abstract void GetParameterValue(string strName, out object
```

```
            objValue);
        public abstract void GetParameterValue(string strName, out string
            strValue);
        public abstract void GetParameterValue(string strName, out short
            shtValue);
        public abstract void GetParameterValue(string strName, out int
            intValue);
        public abstract void GetParameterValue(string strName, out Double
            dblValue);
        public abstract void GetParameterValue(string strName, out Decimal
            decValue);
        public abstract void GetParameterValue(string strName, out long
            lngValue);
public abstract void GetParameterValue(string strName, out DateTime
dateValue);
        public virtual void Dispose()
        {
        }
}
```

One interesting thing about this class is that it implements `IDisposable` interface. This interface only has one method Dispose, for which implementation has to be provided by the class, which implements that interface. As we know, in .NET Framework, Garbage Collection handles the object cleanup. However, it is recommended that if you are dealing with precious system resources, such as database connections, in your class then you should expose a Dispose method. In that method you should properly cleanup those resources. Applications using the objects of your class should call this method to properly and timely free the system resources.

As we know that classes derived from DBAccess encapsulates important system resources such as database connection. It is possible in some cases that an object of type DBAccess is de-referenced but Garbage Collector may take some time to collect. In that case, the database connection that is encapsulated by the subclass of DBAccess will not be freed until the Garbage collection takes place. This is not a desirable behavior and may consume resources on the database sever. That's where use of Dispose method comes into the picture. We can put all the database connection cleanup code in the Dispose method. An application that is using an object of class DBAccess will call Dispose to free up any database resources. Note that classes such as DBAccessSQL, which is derived from DBAccess implements IDisposable inherently because it is implemented in its base class.

As you can see none of the functionality in the abstract base class DBAccess is provider specific. All the properties and functions of base class DBAccess, which are declared abstract, will require implementation in the derived classes. All the provider specific functionality is implemented in the derived classes. It will be a lot clearer when we start looking at the different subclasses of DBAccess class. Let's look at the code shown below for DBAccessSQL:

```
internal class DBAccessSQL : DBAccess
{
private SqlConnection mobjConnection = null;
        private SqlCommand mobjCommand = null;
        private SqlDataAdapter mobjDataAdapter = null;
        private SqlTransaction mobjTransaction = null;
        internal DBAccessSQL(string strConnectionInfo)
        {
                mstrConnectionInfo = strConnectionInfo;
                mobjCommand = new SqlCommand();
                mobjDataAdapter = new SqlDataAdapter();
        }
        internal DBAccessSQL()
        {
                mstrConnectionInfo = "";
                mobjCommand = new SqlCommand();
                mobjDataAdapter = new SqlDataAdapter();
        }
```

Class `DBAccessSQL` is derived from `DBAccess`. Access modified for class `DBAccess` is "public" while access modifier for `DBAccessSQL` is "internal". Access modifier "internal" makes sure that this class is not visible outside its own namespace. Therefore, when we build `DataManager` component as a DLL, consumers will not be able to create the instances of class `DBAccessSQL` directly. They will only be able to create them through the creator class `DataManager`. That is exactly what we want. In addition, `DBAccessSQL` declares objects of type `SqlConnection`, `SqlCommand` and `SqlDataAdapter` as data member. Data members of the class mobjCommand and mobjDataAdapters are initialized in the object's constructor. You can set value of data member mstConnectionInfo in different ways. One way is that when you call `GetDBAccess` method of class

DataManager, you can pass connection string as one of the parameters. Another way to set this information is by calling property ConnectioInfo of class DBAccessSQL. Whatever way you set this property, you have to do it before calling functions Execute or BeginTransaction. Otherwise, an SQLException will be thrown by the Managed Provider.

One benefit that we get from building a wrapper around the ADO.NET data access functionality is that we are able to hide complex implementation details from the consumer of the component. For example, you know that to get a DataSet build based on the results returned from a query, we have to use the Command object of DataAdapter class. For a query that returns no results, we can use Command object directly. As you can see from the code listed above, function Execute has four overloads. Each of them returns a different type of object as out parameters. These overloads of function Execute hide the complex details on how different data access objects such as DataReader or DataSet was created.

```
public override void SetParameter(string strName, ParameterDirection pdDirection,
ParameterType ptType)
{
	try
	{
	SqlParameter objParameter = mobjCommand.Parameters.Add(strName,
	     GetSqlParameterType(ptType));
	                    objParameter.Direction = pdDirection;
	}

	//Exception Handling Code Here
}
```

Code for one of the overloads of function SetParameter is shown above. Overloads of the function SetParameter are used to add parameter to the Parameters collection of Command object for the query or the stored procedure to be executed. As you can see, function SetParameter does not take any of the Provider dependent parameter types as parameter. It takes enumeration ParameterType declared in file DataManager.cs as a parameter for this function. This enumeration abstracts out the differences between the parameters types used by different Managed Providers. It is the responsibility of the derived class of DBAccess to convert it to Provider-Specific parameter type. On thing to note here is that we always add a parameter to the Parameters collection of mobjCommand data member. So, what happens when the overload of function Execute is called that uses data member mobjDataAdapter ? In that case function BindParameters is called by the Execute function, which copies parameters from data member mobjCommand's Parameters collection to the Parameters collection of mobjDataAdapter's SelectCommand property. Listing for function BindParameter is shown below:

```
private void BindParameters (SqlCommand objCommand)
{
	if (mobjCommand.Parameters.Count  > 0)
	{
	foreach(SqlParameter objParameter in mobjCommand.Parameters)
	{
SqlParameter objNewParameter =
objCommand.Parameters.Add(objParameter.ParameterName,objParameter.SqlDbType,objParameter
objNewParameter.Value = objParameter.Value;
	objNewParameter.Direction = objParameter.Direction;
	}
	}
}
```

Now let's look at the code for some of the more interesting functions of class DBAccessSQL. Following is the code for one of the overloads of function Execute:

```
public override void Execute(CommandType ctStatement, string strSQL)
{
	try
	{
		CreateConnection();
		SetCommandData(mobjCommand,ctStatement,strSQL);
		mobjCommand.ExecuteNonQuery();
	}

	//Exception Handling Code Here
}
```

This function is pretty simple. Parameters to this function are enumeration `CommandType`, which may be a stored procedure, name of a table or an SQL query and the statement text itself. This function first calls `CreateConnection`. Function `CreateConnection` is responsible for creating and opening the database connection if one does not exists. It does so by checking data member `mobjConnection`. If data member `mobjConnection` is not null and its state is Open, this function does not do anything. Otherwise, it creates and opens a new `SQLConnection` object and assigns it to data member `mobjConnection`. As said before, it is recommended that as soon as you are done with an instance of class DBAccessSQL, you should call its `Dispose` method. `Dispose` method takes care of closing the database connection. The reason why it is done this way is to follow the principle of getting a system resource as late as possible and releasing it as early as possible once it is no longer required. This way no one holds precious system resources for too long and their availability is maximized. A complete example on the sequence of how different methods of this class should be called will be explained in a later section.

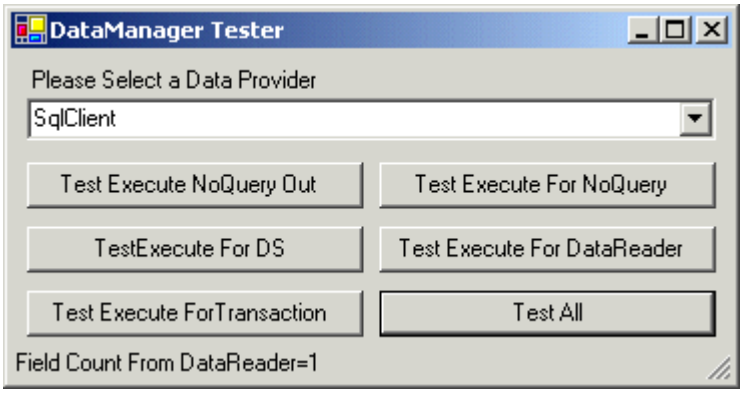
Finally, function `GetParameterValue` that has eight overloads is used to extract the value of parameters returned after executing a stored procedure. Each overload returns a parameter of a specific type as out parameter. Function `ClearParameters` just clears out all the parameters that are set by calling function `SetParameter`. If there is no parameter set by calling function `SetParameter`, this function does not do anything. As mentioned earlier, overloads for function `GetParameterValue` are used to extract the value of the parameters returned by the stored procedure. As you can see from the code shown below for one of the overloads of this function, it simply gets the parameter value from `mobjCommand's` Parameters collection.

```
public override void GetParameterValue(string strName, out object objValue)
{
        try
        {
                objValue = mobjCommand.Parameters[strName].Value;
        }

        //Exception Handling Code Here
}
```

Testing

In the code download there is an application called `DataManagerTest` that we will use to test this component. We will use the pubs database that comes with MS SQL Server as our test database. As you can see from the screenshot below, that each buttons is to test a specific functionality.



First let me show you how we will use this component. The partial code for one of the button onclick event is shown below:

```
DBAccess objABAccess = DataManager.GetDBAccessor(ptType,mstrConnectionInfo);
objABAccess.SetParameter("@JobId",ParameterDirection.Input,ParameterType.dmPtSmallInt,2,
objABAccess.SetParameter("@JobDesc",ParameterDirection.Output,ParameterType.dmPtVarChar,
objABAccess.Execute(CommandType.StoredProcedure,strSQL);
objABAccess.GetParameterValue("@JobDesc",out strJobDesc);
objABAccess.Dispose();
```

As you can see, we first get a reference of a new `objDBAccess` component by calling `GetDBAccessor` method of DataManager with proper `ProviderType` enumeration value. Then parameters are assigned to that component by calling function `SetParameter`. The next step is to call Execute method with proper `CommandType` and SQL text. If the command type is stored procedure and the stored procedure has any output parameters, you can use overloads of function `GetParameterValue` to extract their values. Finally, once you are done with the `DBAccess`

object then it is highly recommended that you call its Dispose method to cleanup system resources in a timely manner. If you want to reuse the same DBAccess object then do not call its `Dispose` method. However, make sure to call its function `ClearParameters` to safely remove all the parameters that were assigned to this object before. You should call `ClearParameters` before you do anything else with the `DBAccess` object. Partial code for this `DBAccess` reuse is shown below:

```
DBAccess objABAccess = DataManager.GetDBAccessor(ptType,mstrConnectionInfo);
//Code for SetParameters
//Code to Call Execute
//Code to Get Parametrs or Deal with Data Set
//Make Sure you call Clear Paramaetrs before you do anything
objABAccess.ClearParameters()
//Code to Reuse the same object
//Code to SetParameters
//Code to Call Execute
//Code to Get Parametrs or Deal with Data Set
//Once you are done then call Dispose
objABAccess.Dispose();
```

Tools and Technologies Used

We will be using the following tools and technologies to build this component.

- . NET Framework Beta 2
- Visual Studio .NET Beta 2
- Windows 2000 Server or Professional
- Internet Information Server 5.0
- C#
- SQL Sever 7.0 or 2000

Conclusion

This completes our discussion regarding this article. `DBAccessOleDb` is the other class that is derived from DBAccess. It works pretty much the same was as `DBAccessSQL`. There is some functionality, which is only available in Managed Provider for SQL Server. To support that kind of functionality you have two options: One, that you can somehow implement that functionality yourself, the other being to throw a proper exception. Some other features that we may want to implement later are bulk updates using DataSet and DataAdapter.

One other thing to note here is how straightforward Object Oriented development is with .NET Framework. With classic COM, only interface inheritance was possible. So to develop an application based on complex Object Oriented designs you had to improvise and use roundabout techniques. However, with .NET Framework both interface inheritance and implementation inheritance are available. This way any type of Object Oriented implementation is possible using the .NET Framework. You are not forced to convert your OO classes to interfaces to make things work, as you had to do in the case of classic COM. In addition, you can take advantage of different OO techniques without any problem.

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